OTSM Network of Problems for representing and analysing problem situations with computer support

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Abstract. This paper presents a method for increasing the level of formalization of the description of a problem situation and obtaining a "big picture" of the problem situation in order to be solved by TRIZ and OTSM instruments. The main output of the method is a list of problems to be turned into contradictions. Elements concerning computer support for this approach are discussed.

Keywords. TRIZ, OTSM, inventive problem solving, computer aided innovation.

1 Introduction

Before setting out on a complex journey we usually prefer to have a good map of the destination, but when researching in new territories for which no map exists, we have to develop our own map while exploring the area. Analysis of complex non-typical interdisciplinary problem situations could be viewed as a journey into unknown territories. Therefore it is also a good idea to develop maps of the elements of the thought process we pass through. This map will guide us through complex problem situations and help, on the one hand, to collect a set of partial solutions we could use in order to develop satisfactory solutions, and on the other hand, get an holistic view of the links between the problems.

Several problem solving methods and tools based on the idea of a map have been proposed in the past in the area of systems engineering and management like KJ diagram [1], causal loops diagram [2]. Most of these general tools just describe systems and problem relationships and leave the human problem solvers responsible for analyzing and solving the problem. When the cognitive gap between the description of the problem and the description of the solution is too large for the

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problem solver additional tools are required. TRIZ [3-6] and OTSM [7-17] [18, 19] theories provide instruments which satisfy this need when the path from problem to solution involves changes in the model of the problem or system. This paper presents a method for increasing the level of formalization of the description of a problem situation and obtaining a "big picture" of the problem situation in order to be solved by TRIZ and OTSM instruments with or without computer support. It is based on the so called "Network of Problems" (NoP) concept and analysis technique which is part of OTSM instruments. It can also be used for problem situation analysis and resolution independently of further use of OTSM problem solving methods. Indeed, as it collects, formalizes and organizes knowledge and information about the problem situation, it can be used at least as any general problem analysis method. Nevertheless, in this paper, we shall focus on the analysis that leads to obtaining the network of contradictions which are to be overcome by the team of professionals and experts in order to solve the addressed problems.

1.1 TRIZ in brief

TRIZ is a theory for solving problems during the inventive process. It provides a set of instruments which dramatically decrease the amount of trial-and-errors when a problem situation requires creativity and invention in order to be solved. It was created in the course of an extensive study of the history of engineering systems evolution. As a result of this study three postulates were formulated.

(1) Postulate of objective laws of system evolution. Genrich Altshuller developed a system of 8 laws of engineering system evolution. Based on this system, an instrument for practical needs was developed known as the TRIZ system of standard solutions for inventive problem solving.

(2) The postulate of contradiction states that behind each non typical problem there is a hidden contradiction that should be discovered and overcome in order to solve the problem and reach the next step of engineering system evolution. Based on this postulate, instruments for dealing with contradictions have been developed. The most sophisticated of them, in the framework of Altshuller's work, is ARIZ-85-C, which is a meta-method using most of the basic TRIZ instruments. ARIZ helps to clarify and solve the underlying core contradiction of a problem. ARIZ is also helpful for transforming a problem that seems atypical at the beginning into a typical TRIZ problem description. Then the TRIZ system of standards (typical solutions) could be applied. In case a problem could not be solved by TRIZ typical solutions ARIZ has special tools for dealing with non typical problems.

(3) The postulate of specific situations states that in the course of the problem solving process we should focus on the peculiarities of the problem situation and use available resources of the specific situation in order to study the situation and to construct a satisfactory solution.

ARIZ-85-C integrated all instruments of Classical TRIZ in the united system and based on the theoretical background of Classical TRIZ. In order to develop ARIZ and use general ideas of the axioms in real life situations two main models were also proposed in Classical TRIZ: System operator [6], which is dedicated to describe a problem situation as a whole and its elements in order to simplify the problem solving process; and the TRIZ model of the problem solving process [20].

1.2 OTSM in brief

OTSM develops Classical TRIZ ideas further in order to propose instruments to deal with non typical complex interdisciplinary problem situations. The main problem to tackle can be formulated as a question: how to transform all possible problems of invention into one canonical form in order to solve them by a typical problem solving procedure? What should be the canonical form and the procedure for obtaining it?

In the course of our research the driving contradiction that underlies the key questions to be answered by OTSM was indentified: In order to create universal instruments, the rules of these instruments should be as general as possible. But, usually, general rules propose general recommendations that are useless for practice. It means that in order to be useful for real life practice, the rules of the instruments should be specific. But, the more specific the rules are, the narrower the scope of their applications. This contradiction was resolved by using instruments of Classical TRIZ. Then the system of OTSM axioms was developed and axioms of Classical TRIZ were reformulated according to the results of OTSM development. Two models of Classical TRIZ proposed by Altshuller were reviewed and developed further for OTSM purposes. The most important instruments of OTSM are the four main technologies: New Problem technology, Typical Solution technology, Contradiction technology and Problem Flow technology. These technologies are integrated into the Problem Flow Networks approach (PFN) [15] [17, 21] [14] [22]. PFN approach is based on four kinds of networks: Network of Problems; Contradiction Network, Parameter Network (Specific) and Parameter Network [17].

In this paper, we present a method for developing and analyzing the NoP in order to transfer it into a network of contradictions which are to be solved. This method was implemented for the improvement of a power plant. As a result, in March 2006 a patent was obtained. The remaining part of the paper is organized in the following way. First are provided basics about the NoP and an overview of the proposed process. Second the process is described step by step. Third, computer support for this approach is discussed before the conclusion.

2 Using the network of problems (general) for analysis

2.1 Basic concepts of the network (solutions, partial solutions, edges)

The Network of Problems, which is a high level representation of the problem situation that both gathers and analyzes overall knowledge of the initial situation, can be considered as a semantic network linking several aspects of a many-sided problem situation. The NoP can be considered as an oriented graph the nodes of which represent either problems partial solutions or goals. We define a partial solution as a solution that cannot be generally accepted for one of the following two reasons: (1) the solution solves one problem but produces another one (chain of problems); (2) the solution solves just one or several sub-problems but not the problem situation completely (Sub-domain of the whole problem domain). Goals are specific kinds of problems that will be defined in section 4. The edge meanings are given on Fig. 1.

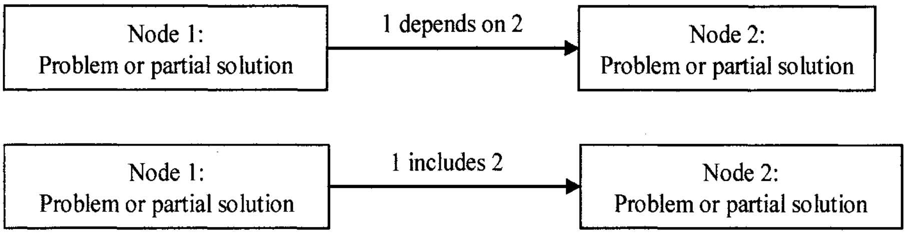

Fig. 1. Example of the meaning of the arrows of the Network of Problems

The terminology "super-problem" and "sub-problem" of a given problem are used in reference to the path linking two problems. It is only relevant when the path is not part of a closed loop. A problem A is a super-problem A of a problem B when there exists a pathi from problem A node to problem B node. Inversely in the same situation problem B is a sub problem of problem A. A problem can be both super and sub-problem.

2.2 Overview of the process

The first stage of development of the NoP (S1 to S5 in the flowchart Fig. 2) starts by collecting a list of the most painful problems and their potential or partial solutions. Then, relationships between problems and solutions are established. Next, analysis of the actual problem situation is performed according to Classical TRIZ System Operators, a list is compiled of the problems related to certain components of the system and stages of the process the system should perform. As a result of this analysis, a list of problems and partial solution is updated and corrected.

During the second stage (S6 to S12 in the flowchart), the previous list is transformed into a NoP. During this stage, some initial descriptions of problems and potential solutions may be decomposed into sub-problems and solutions. As a result, a map is formed which described the whole problem in a more formalized way. In addition, when the map is developed by a group, it helps to obtain mutual and shared understanding of the problem situation and of the goals to be achieved.

The third stage (S13 to S15) is dedicated to identification and analysis of bottlenecks, which are the most important problems that should be eliminated or bypassed in the course of the problem solving process. Sometimes the problem situation can be resolved at this stage if the participants in the problem solving session have all the necessary skills. Otherwise, the problem solving process goes on by stating contradictions and building OTSM's network of contradictions, which is out of the scope of this paper.

3 The analysis procedure step by step (see also flowchart)

3.1 The initial list of problems

First, an initial list of the most painful problems should be drawn up without any specific organization. Members of the problem solving team individually or in groups prepare lists of problems which they consider as the most important and painful problems. Each item of the list is a short description of the problem in free form. Then problem description should be clarified with OTSM experts. Eventually participants learn the rules for initial problem representation in the list of problems. If some partial solutions of the problems can be proposed, they have to be collected too.

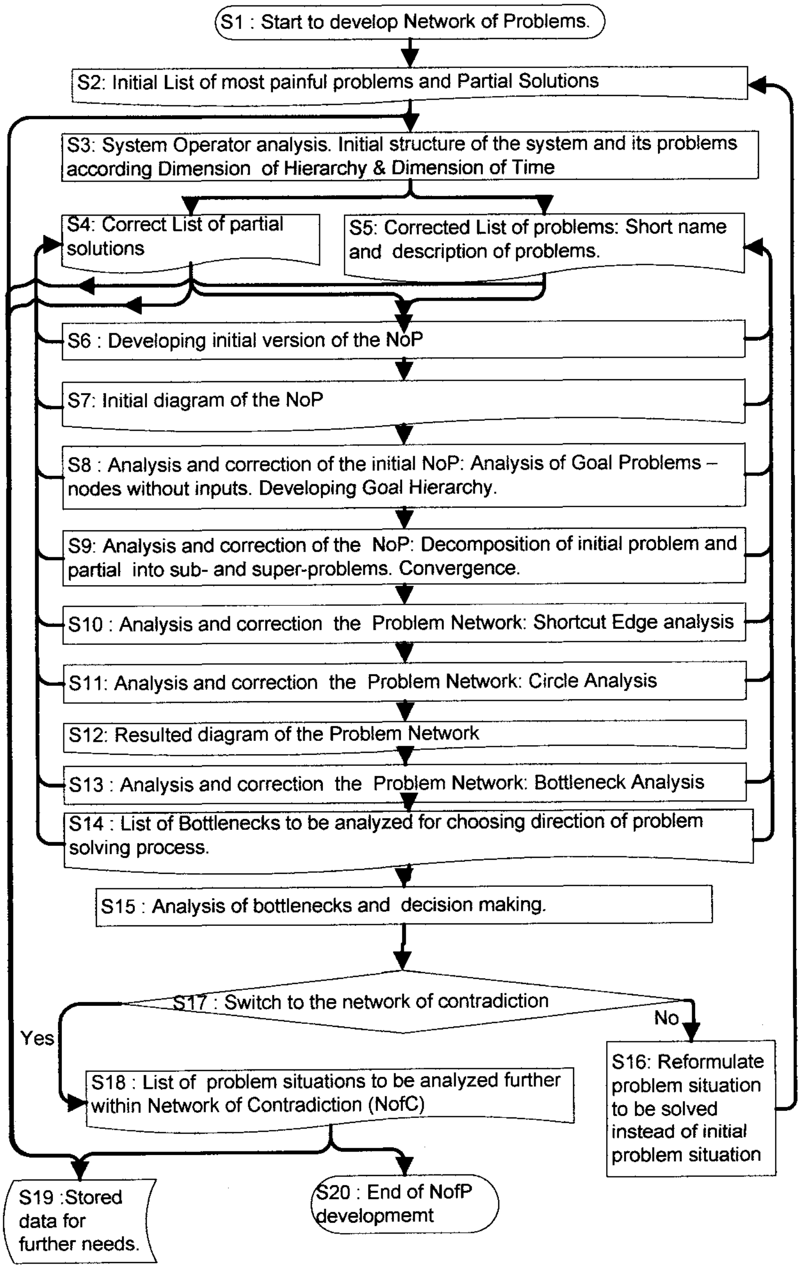

Fig. 2. Flow chart of the NoP analysis

3.2 System Operator analysis of the problem situationii

It can be observed from the list of problems that each problem belongs to a certain level of system hierarchy (Hierarchy Dimension) and stage of the process that the system should perform according its function (Time Dimension). Thus, the next stage consists in creating a hierarchical schema of the existing or hypothetical system (in case the system is under development) and its technological process (Time Dimension of Classical TRIZ System Operator). This process will reveal additional problems. Each of these problems is relevant to a certain level of the system hierarchy. Therefore groups of problems should be analyzed by level of this hierarchy.

For each additional problem identified during this stage, linked partial solutions should be collected. Any other techniques and methods could also be used in order to update the initial list of problems for the given problem situation. As soon as no new problem appears from Domain Experts, the initial problem network development can start.

3.3 Developing the initial version of the Problem Network

The goal of this stage is to establish a relationship between problems and partial solutions in the form of a semantic network (Oriented named graph) like in Fig. 3 below. Problems (Pb) and partial solutions (PS) and, as we will see further, goals are nodes of this network. An arrow linking a problem and a partial solution indicates which problem should be solved or which partial solutions should be implemented in order to solve this problem. When connections between problems and partial solutions are unclear at this stage, but it is likely they are linked, problems and partial solutions are grouped together on the diagram for further clarification of their relationships like in Fig. 4.

Several practical rules for representing the graph, which facilitate further human visual analysis, are used: (1) Arrows should go out of the node box from the bottom side and come into the node box from the top side of the box; (2) problems and partial solution nodes have different colors; (3) the arrows and level of the graph are oriented from the top to the bottom of the page.

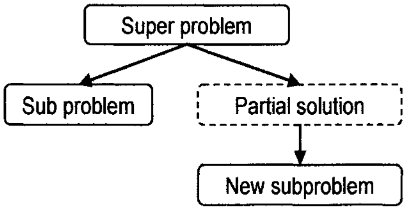

Fig. 3. Arrow direction: from top to down. From super-node to a sub-node

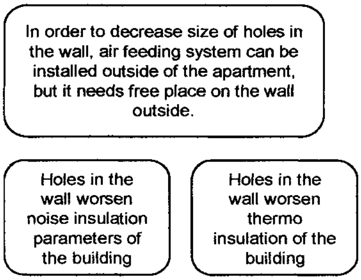

Fig. 4. Sub-set of nodes for further clarification of their relationships with other nodes

The initial network of problems is ready to be analyzed and improved when each problem and sub problem is connected to an arrow.

3.4 Goal analysis

At this stage, one should focus on the nodes of the graph that have no incoming arrow. They should be considered as Goals to be achieved. It is necessary to organize them into a system of goals by establishing relationships between goal nodes. Organizing Goal Nodes reveals the set of criteria of good solutions. Good solutions are solutions that help us to solve the top goal problems.

According to the rules of representation given above , these nodes should be located at the top of the graphical representation of the Network of Problems.

3.5 Decomposition of problem and solution descriptions

When general criteria concerning the evolution of the required solutions are available, some problems and solutions may be decomposed. Sometimes the problem description contains descriptions of partial solutions as well. Other problem descriptions, which are sub-problems due to implementation of certain partial solutions, may appear. Some partial solutions can be decomposed into several partial solutions or a sub-network of problems and partial solutions.

All of these sub-graphs should be properly integrated into the initial NoP. After a certain amount of practice, decomposition of the problem and solution nodes could be done at earlier stages of the initial NoP development and even whilst gathering problems for the list of initial problems. But at the beginning, it is better to focus on decomposition after organizing the Goal Nodes into a system.

It is important to notice that sometimes decomposition of problem and solution descriptions could lead to a particularly large sub-network of problems. According to the OTSM model of non typical problems, the problem solving process should be presented as a fractal structure. That is why some problems or solutions can be deployed into a sub-network of problems and each network of problems has to be considered as part of a Super-network of problems. For instance the network of problems relevant to a certain project of a company is a sub-network of the whole company Network of Problems. At the same time some sub-problems of the project could be presented as a large network of problems.

3.6 Short Cut edge (arrow) analysis.

Sometimes situations are present in the graph where several paths from one problem to another do not have the same number of arrows as in Fig. 6. In this case, it has to be clarified why this shortcut appears. Usually, it shows that either some sub problems are missing or useless. Sometimes we can extract additional information about the initial problem situation and rearrange the whole diagram accordingly.

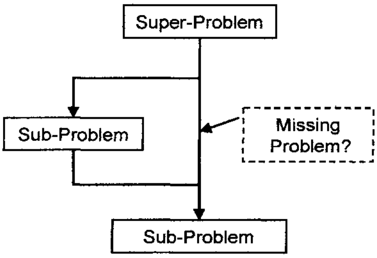

Fig. 5 Shortcut edge

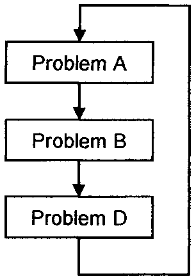

Fig. 6. Closed loop of problems

3.7 Closed loops analysis

Special attention should also be paid to the loops in sub-graphs like in Fig. 6. They often indicate important hidden contradictions or closed loop situations in the problem situation. Generally, additional information should be gathered and/or new sub-problems and solutions disclosed. As soon as the above mentioned analysis is done and all changes in the list of problems are performed, it can be considered that the development of the initial version of the network is finished and a more precise analysis of the obtained problem situation description can begin (S 13 in the flowchart).

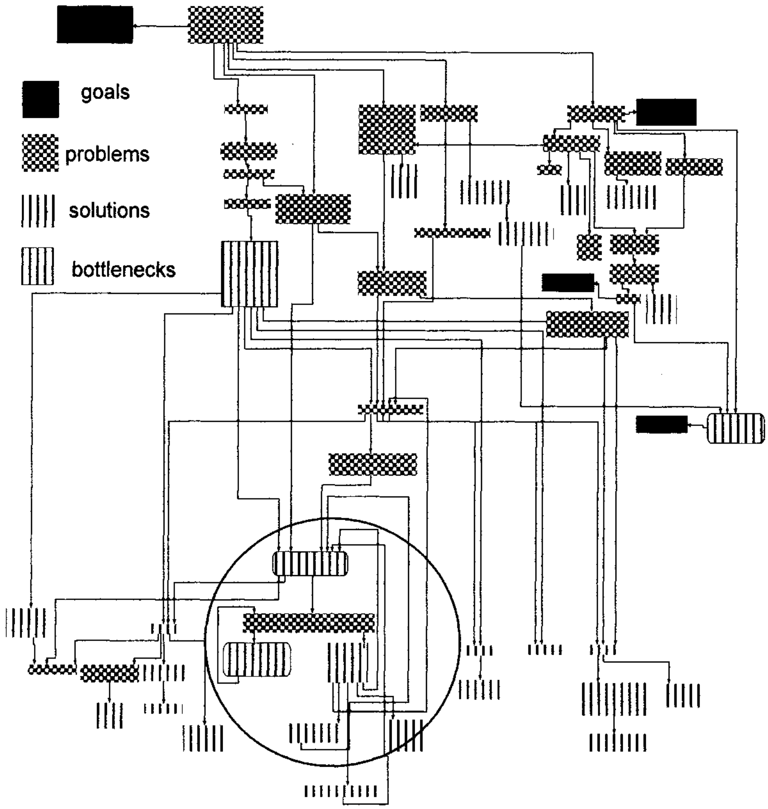

Fig. 7. Example of Network of Problem. In the cercle, the bottleneck at the top is involved in two closed loops.

3.8 Analysis of the bottleneck problems

A bottleneck problem or solution (see Fig. 7) appears as a node of the network that has several inputs from different problems or solutions. Bottleneck nodes often indicate that at least one hidden contradiction exists in the problem of the bottleneck. Often it is a system of contradictions, which will be developped into a network of contradictions[17]. The point is that the solution of several problems of the project depends on the bottleneck problem. Thus, it is meaningful to focus on these kinds of problems first. A NoP may have several bottlenecks. In this case, it is better to choose those which are closer to the Goal node we are dealing with during the problem solving session. The reason of the previous proposal is that each solution will make the network evolve. When a bottleneck problem is solved, problems below the bottleneck in the hierarchy of problems can disappear with all its sub-problems. Often, bottlenecks nearest to the goal in the top of the network are supposed to have many sub-problems sometimes also bottlenecks. Moreover, the bottom of the hierarchy only shows problems or solutions for which we do not know sub-problems.

After each analysis above, the list of problems should be properly corrected, updated and saved for further needs. As soon as bottleneck and other analyses are performed, it is time to choose a set of problems (bottlenecks, loops etc.) in order to formulate a set of contradictions to be transformed into the network of contradictions.

4 Software support for analyzing the Network of problems

Computers can be used and are necessary at several stages of the NoP development. Firstly graphical tools for NoP visualization and layout are necessary. For simple problems, standard tools like Microsoft Visio and several "macros" linking nodes to data bases and problem descriptions are sufficient. Loop, goal and bottleneck identification can be handled visually by the human analyst.

But in the case of large NoPs including several hundreds of sub-problems and partial solutions the capacity for visualization degrades. In this case it could be better to use special software for Graphs or Semantic network analysis. Loops, goals and bottlenecks are standard functions of graph analysis toolboxes. Visual tools for graph hierarchies and clusterings do exist. All these tools can be integrated to build a tool dedicated to this analysis. In practice, we are at the stage of integrating, within a same prototype, tools for NoP development and analysis but also for the next stages of the problem solving process.

5 Conclusion

OTSM based NoPs are useful for beginning the complex cross-disciplinary problem solving process. Experts, from various domains, who take part in the sessions for NoP development, notice that this kind of network is helpful for understanding their own problems and finding a shared view of the problem situation. It can be used in order to increase the efficiency of problem solving sessions and to share and organize knowledge and views which are relevant to a given problem situation. That is why we suggest that a process of solving cross-disciplinary problems which is based on the Network of Problems and OTSM could be used as an instrument for knowledge representation and capitalization for further needs of a company or organization.

Notes

i Sequence of nodes and one outgoing arrow for each node. Path in a graph.
ii System Operator of classical TRIZ is often known as Multi-Screen Schema.

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